United Nations

Framework Convention on Climate Change

Research Dialogue 17

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Seventeenth meeting of the Research Dialogue 2025

Informal summary report by the Chair of the Subsidiary Body for Scientific and Technological Advice

Summary

The seventeenth meeting of the research dialogue took place on Tuesday, 17 June 2025 in conjunction with the sixty-second session of the subsidiary bodies (16–26 June 2025), in Bonn, Germany, on the topics of scientific advances in the understanding of climate change; and climate action and sustainable development nexus. This informal summary report, prepared by the Chair of the Subsidiary Body for Scientific and Technological Advice, provides a summary of the discussions that took place.

Abbreviations and acronyms

AI	Artificial Intelligence
AR	Assessment Report of the IPCC
BECCS	Bioenergy with Carbon Capture and Storage
CDR	carbon dioxide removal
CH4	methane
CMIP	Coupled Model Intercomparison Project
CO_2	carbon dioxide
COP	Conference of the Parties
DACCS	Direct Air Carbon Capture and Storage
DRR	Disaster Risk Reduction
G20	Group of 20
GCP	Global Carbon Project
GHG	greenhouse gas
GPEX	Global Precipitation Experiment
Gt	gigaton
GST	Global stocktake
IAM	Integrated Assessment Models
IKS	Indigenous knowledge systems
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
N_2O	nitrous oxide
NDC	nationally determined contribution
PIK	Potsdam Institute for Climate Impact Research
RD	Meeting of the SBSTA research dialogue
SBSTA	Subsidiary Body for Scientific and Technological Advice
SDG	Sustainable Development Goal
SIDS	Small island developing States
SYR	AR7 Synthesis Report
UNFCCC	United Nations Framework Convention on Climate Change
WG	IPCC Working Group
WMO	World Meteorological Organization

Key messages, 17th meeting of the research dialogue

1. On climate attribution, human activities, through GHG emissions, have unequivocally caused global warming, with higher confidence in relation to hot extremes and heavy precipitation, and lower confidence in relation to agriculture and ecological drought.

2. The IPCC AR7 will continue to address knowledge gaps from AR6 and advance our understanding of climate science, including in relation to climate attribution, Earth system responses under various pathways, and interlinkages of climate change action and sustainable development.

3. The year 2024 was the warmest year on record, with the average mean temperature of ±1.55 °C, and there is a 70 per cent chance that the average mean global temperature for the next 5 years will be 1.5 °C. However, multi-decadal estimates of current global warming are below 1.5 °C and are between 1.34–1.41 °C.

4. Current levels of warming could lead up to 40 per cent loss of glacier mass and accelerated melting of polar ice sheets, which will significantly contribute to sea-level rise, reaching up to 6.5mm per year by 2050.

5. Global emissions of non-CO_2 emissions, particularly CH_4 and N_2O emissions, continues to rise contributing significantly to global warming, and current emissions are not in line with the Paris Agreement goals.

6. CDR can support in achieving net-zero and net-negative emissions in the long term, and further research is required understand its feasibility and related risks and in supporting its upscaling. Scaling-up CDR could be more effective through a diversified CDR portfolio that adopts a holistic and integrated approach.

7. There are more synergies than trade-offs of adaptation and mitigation actions with SDGs, with varying results and consequences within and across countries, which requires strong enabling conditions such as inclusive governance and finance. However, methodological gaps remain in the assessment of the impact of adaptation actions, and contribution to reducing risks, exposure, and vulnerability.

8. Coordinated strategies that advance climate action and sustainable development, can provide co-benefits, especially if deployed early on, for instance towards energy security, urban systems and infrastructure, health and wellbeing, food and water, biodiversity, disaster risk reduction, livelihoods and economies as well as support in advancing the implementation of other global policy frameworks.

9. There is growing recognition on the contribution of Indigenous knowledge to climate research. Co-producing the knowledge through genuine collaborations and addressing methodological gaps during its consideration could maintain its independence and comprehensiveness. IKS can contribute to effective climate actions, particularly those requiring system transformations.

I. Introduction and overview

1. The meetings of the research dialogue offer a vital platform under the SBSTA for Parties, non-Party stakeholders, and the scientific community to engage in an open exchange of information, present recent scientific advances and findings, and discuss related capacity-building needs for advancing the implementation of the Convention and the Paris Agreement. The dialogue is key towards ensuring that global climate policy and action is informed by the best available science.

2. The seventeenth meeting of the research dialogue took place during the 2025 Bonn Climate Change Conference on 17 June. The dialogue's themes were identified based on submissions from Parties and non-Party stakeholders[1] in response to the call for submissions on the same made at SBSTA 60, and in consideration of the wider context of ongoing work under the UNFCCC. Based on the 16 submissions received and informal consultations held by the SBSTA Chair on 24 February 2025, the themes for the dialogue were: (i) Scientific advances in the understanding of climate change; and (ii) Climate action and sustainable development nexus.

3. The first theme of the dialogue focused on latest developments and advancements in understanding climate science such as attribution science, updates on the global climate indicators, impacts of the changing climate across various warming scenarios and tipping points, and an outlook of the changing climate in relation to people and ecosystems. The second theme examined interdisciplinary research on equitable and context-specific pathways that link climate action to sustainable development priorities such as biodiversity conservation, poverty eradication, job creation, energy security, infrastructure development, and DRR. The following guiding questions where shared in advance of the dialogue to inform discussions during the event:

(a) What recent scientific advancements and progress have been made at global and regional levels?

(b) What research needs and knowledge gaps remain, and what efforts are underway to address them?

4. The dialogue included a high-level opening plenary, two parallel breakout sessions, and an interactive poster session. The event was held under the overall guidance of the SBSTA Chair, Adonia Ayebare and facilitated by the SBSTA Vice-Chair, Carol Franco. An information note summarizing the scope, themes and structure of RD 17 as well as agenda for the dialogue were published[2] ahead of the session.

5. This report captures the key proceedings and outcomes from the plenary discussions, breakout sessions, and poster interactions, which also informed negotiations during the session on research and systematic observation under SBSTA agenda item 4.[3]

II. Summary of proceedings

A. High-level opening segment and plenary

Opening remarks

6. The Vice-Chair of the SBSTA, Carol Franco, in welcoming participants to the dialogue emphasized the role of the research dialogue in providing a platform for exchange of information and interface with the scientific community. She highlighted the themes for the dialogue, which were informed by submissions and informal consultations that were held, and further acknowledged the growing scope of topics and interest in the dialogue. She also highlighted the participatory nature of the dialogue's format aimed at providing adequate

[1] Available at https://www4.unfccc.int/sites/submissionsstaging/Pages/Home.aspx (in the search field, type "research", and select "2025").
[2] Available at https://unfccc.int/event/seventeenth-meeting-of-the-research-dialogue-mandated-event.
[3] See https://unfccc.int/documents/648220.

avenues for engagement. Participants at the dialogue were encouraged discuss and engage on the latest scientific findings, and gaps in research and knowledge, in line with the dialogue's guiding questions.

7. In her remarks, Annett Moehner, manager of the Collective Progress Subdivision at the UNFCCC highlighted the critical role that science plays in informing climate policy and action. She elaborated on how the dialogue's themes and its organization were aimed at responding to the needs of Parties and non-Party stakeholders. She recognized the ongoing challenges related to advancing research, particularly in developing countries as well as the growing complexity of knowledge needs in advancing the implementation of the Convention and Paris Agreement. In closing, she commended the existing partnership and continued contribution with the scientific community and relevant organizations in supporting the organization and delivery of the dialogue.

Key address and updates by the IPCC

8. The Chair of the IPCC, Jim Skea in his keynote address[4] reiterated the urgency in responding to climate change and provided an update of work under the AR7 and its outputs[5]. He elaborated that the special report on climate change and cities, and methodology report on short-lived climate forcers, to be released in 2027, have been scoped and the authors selected. The scope of the methodology report on CDR technologies, carbon capture utilization and storage and SYR are yet to be agreed by the panel. Further, the panel agreed to the outlines of the three WG reports while their timelines are yet to be finalized, with an expectation of production from mid-2028, and the SYR to be approved by late 2029. The updated technical guidelines on impacts, adaptation and vulnerability will be produced alongside the WG II report.

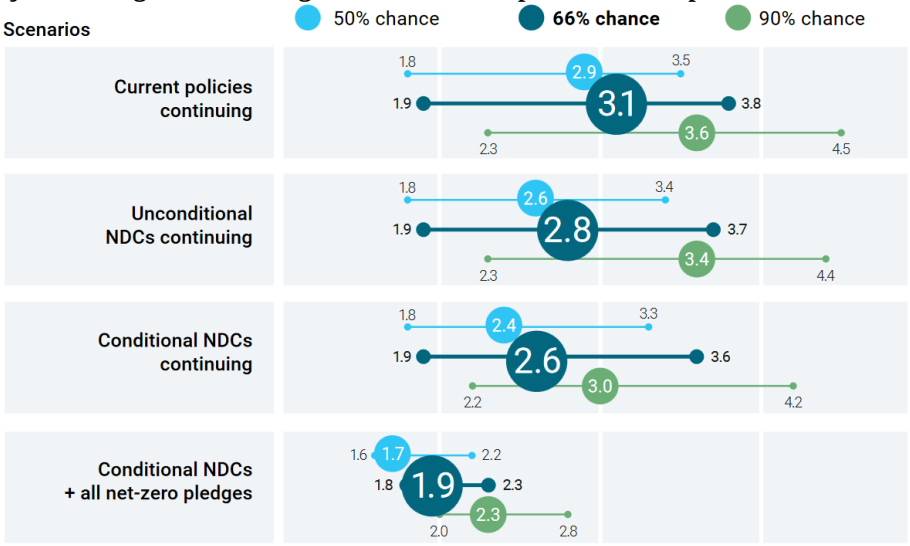
9. In relation to scientific developments, Jim Skea reiterated the state of the knowledge during AR6 and elaborated on how knowledge gaps since AR6 will be treated in AR7. On attribution, he recalled AR6 which indicated that human activities, principally through emissions of GHGs, have unequivocally caused global warming, for instance as observed through hot extremes and intensification of heavy precipitation, with high confidence. However, he highlighted that there is lower confidence, in part due to lower level of consensus in assessed literature, in relation to human influence on agricultural and ecological droughts. AR7 will therefore address lower confidence topics with the view of reaching consensus, and deepen understanding of attribution, such as attribution of local changes and extreme events. To support this, WG I will explore kilometre-scale climate simulations and use of climate emulators and AI, and WG II will assess attribution to observed and projected impacts.

10. On current warming levels, and in accordance with the WMO, Skea presented that the annual average global mean temperature of 2024 was ±1.55 °C above pre-industrial levels, while long-term warming varies between 1.34 °C and 1.41 °C. He demonstrated that there are pathways that both exceed 1.5 °C in the short-term and limit warming to the same level by end of the century. However, GHG emissions are rising and projected at 2 °C by end of the century if all NDCs and net-zero pledges are met, as shown in figure 1 below. AR7 will cover overshoot, including temporarily, and its consequences; however, there are significant knowledge gaps, particularly in understanding irreversible impacts. He further elaborated that WG I will address Earth system responses, WG III will assess the potentials, limits and risks of CDR and WG II will assess implications for human and natural systems while the task force on inventories will develop the related methodologies.

[4] See https://www.ipcc.ch/2025/06/17/keynote-jim-skea-research-dialogue-sbsta62/.
[5] See https://www.ipcc.ch/assessment-report/ar7/.

Figure 1

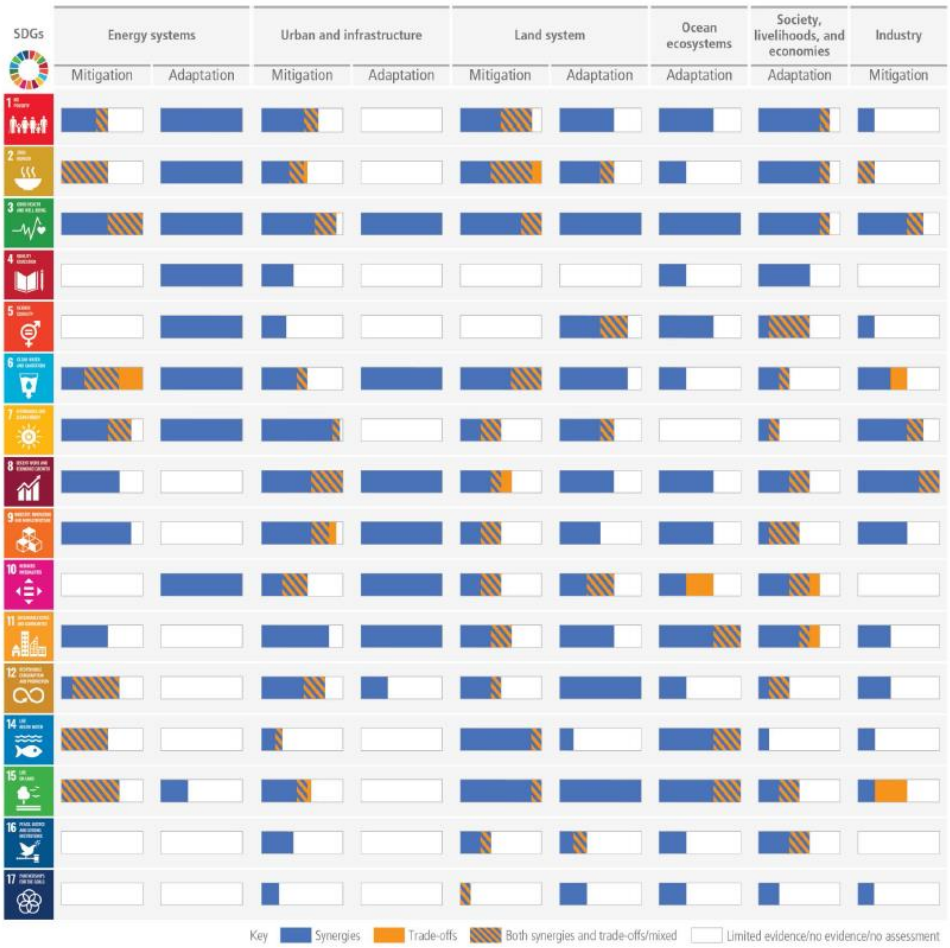
Projections of global warming based on current policies and implementation of NDCs



Source: Slide 10 of the presentation by Prof Jim Skea at the RD 17, from the UNEP Emissions Gap Report 2024. Available at https://unfccc.int/documents/647801.

11. AR7 will also focus on impacts of adaptation, where there is a current lack of means to measure its progress. The technical guidelines on assessing impacts of adaptation will aim at filling this gap as well as work under the global goal on adaptation. WG II will also include a chapter on finance, an enabler for adaptation. Jim Skea also illustrated how AR7 will consider the interlinkages between climate action and sustainable development. Specifically, he elaborated that adaptation and mitigation actions have more synergies than trade-offs with SDGs, as reflected in figure 2 below. WG II will address responses to loss and damage and WG III will discuss synergies and trade-offs, distributional consequences of mitigation actions, equity and justice and interlinkages with biodiversity conservation and pathways that consider sustainable development. He reiterated the IPCC's unique role in synthesizing the rapidly growing body of knowledge, providing robust, contextual and comprehensive information with high level of confidence, and in effectively informing policy.

Figure 2
Synergies and trade-offs of near-term adaptation and mitigation options with Sustainable Development Goals



Source: Slide 16 of the presentation by Prof Jim Skea at the RD 17. Available at https://unfccc.int/documents/647801.

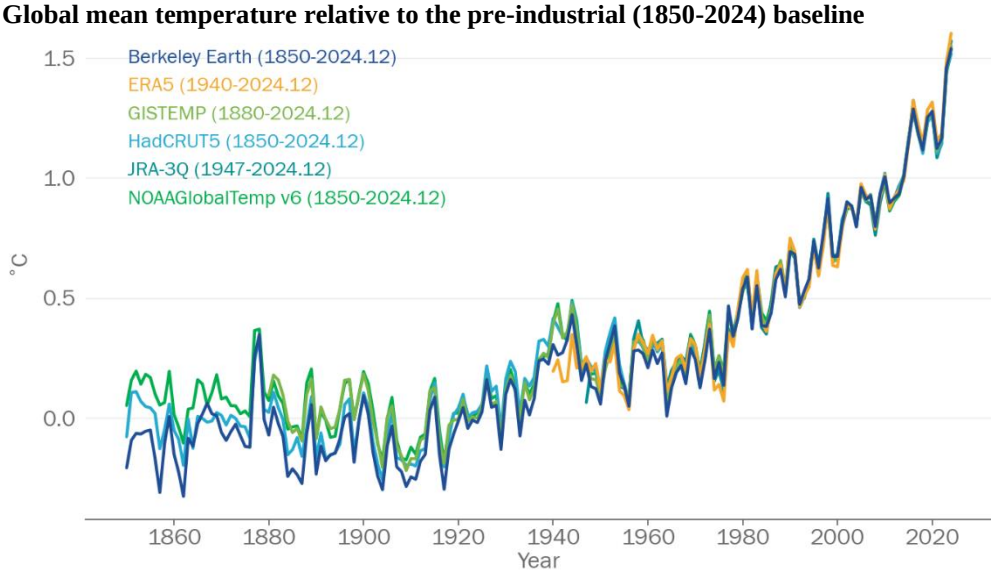
12. The Co-Chairs of WG I, Xiaoye Zhang and Robert Vautard, presented an update on the current assessment and work under the group, with a focus on new information to be assessed in AR7. Zhang explained that the selection of authors by the bureau is currently underway following the approval of the outline of the WG I report by the panel. The WG I will be structured into three main blocks with a focus on; (i) current situation and trends (Chapter 2–4), (ii) future climate (Chapter 5-8), and (iii) information for response (Chapter 9 and 10, and interactive atlas). Accordingly, Chapters 2, 3, and 4 will discuss large-scale system changes, changes in regional climates including extremes and advances in understanding the Earth system changes respectively.

13. Under AR7 WG I, Chapter 5 will discuss future global warming in response to emissions and land-use projections and seek more consistent and coherent scenarios compared with AR6. Further, the likelihood of events including abrupt changes, low-likelihood high-impacts events and critical climate thresholds such as tipping points, their drivers and regional consequences, will be discussed in Chapter 8. Chapter 9, a new chapter in AR 7, will assess Earth system responses to pathways towards temperature stabilization including overshoot pathways. It will discuss constraints related to Earth system feedbacks, limits of CDR and responses to solar radiation modification and provide policy relevant information including long-term implications. Chapter 10 will discuss how science is applied, for instance for impact and risk assessments, adaptation, and mitigation, and climate information and services in the near-term.

State of the Global Climate: annual and decadal updates by WMO

14. The director of climate services at the WMO, Chris Hewitt, provided an annual and decadal update on the state of the global climate, based on the WMO State of the Global Climate 2024[6] and WMO Global Annual to Decadal Climate Update 2025–2029.[7] According to the WMO State of the Global Climate 2024, the year 2024 was the warmest year on record, with a global mean temperature of 1.55±0.13 °C above the 1850–1900 average period as shown in figure 3, and that CO_2 concentration was high.

Figure 3
Global mean temperature relative to the pre-industrial (1850-2024) baseline



Source: Slide 3 of the presentation by Prof Chris Hewitt at the RD 17. Available at https://unfccc.int/documents/647806.

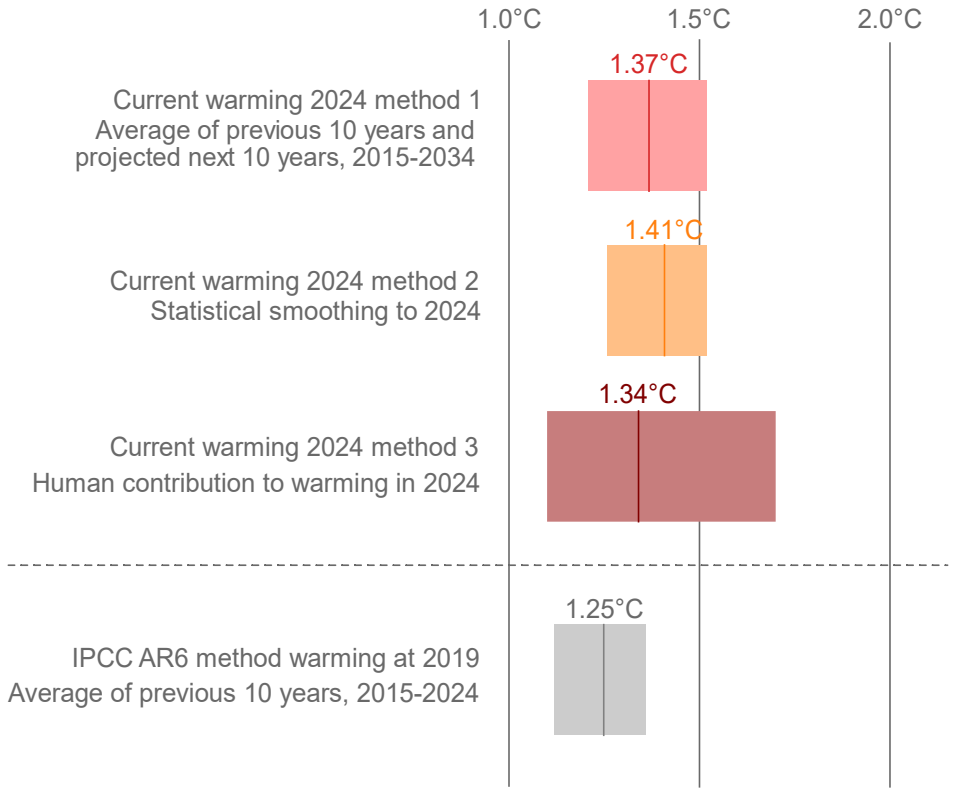
15. Further, the most negative glacier mass balance was recorded from 2021–2024, and the Arctic and Antarctic Sea ice extent were both below average in 2024. Artic sea ice experienced gradual decrease over a long period while Antarctic had changes from approximately 10 years ago. The report also highlighted that ocean heat content and global mean sea-level reached highest levels in 2024, and acidification of the ocean surface continued over the past 39 years. Hewitt also reported extreme events occurring globally including wildfires, heatwaves, floods and droughts.

16. The WMO Global Annual to Decadal Climate update indicated that there is a 70 per cent chance that the five-year average warming for the year 2025-2029 will be above 1.5 °C, and that at least one of the next five years will be the warmest on record. The report also provides information of distribution of temperature forecasts, providing regional information, and for instance, indicating that the Arctic warming is expected to outstrip global average warming. In regards long-term warming, Hewitt signalled that according to best current estimates, long-term global warming remains below 1.5 °C as demonstrated across many studies, reflected in figure 4 below. He, however stressed that, every fraction of a degree of warming matters, particularly for the cryosphere, with impacts on sea-level rise and ocean heat content. To support the provision of up-to-date information on long-term warming, WMO has established an international team of experts to define the metrics for long-term warming.

[6] WMO. 2025. *State of the Global Climate 2024*. Geneva: WMO. Available at https://library.wmo.int/records/item/69455-state-of-the-global-climate-2024.

[7] WMO. 2025. *WMO Global Annual to Decadal Climate Update (2025–2029)*. Geneva: WMO. Available at https://wmo.int/sites/default/files/2025-05/WMO_GADCU_2025-2029_Final.pdf.

Figure 4
Long-term global warming projections and estimates



Source: Slide 9 of the presentation by Prof Chris Hewitt at the RD 17. Available at https://unfccc.int/documents/647806.

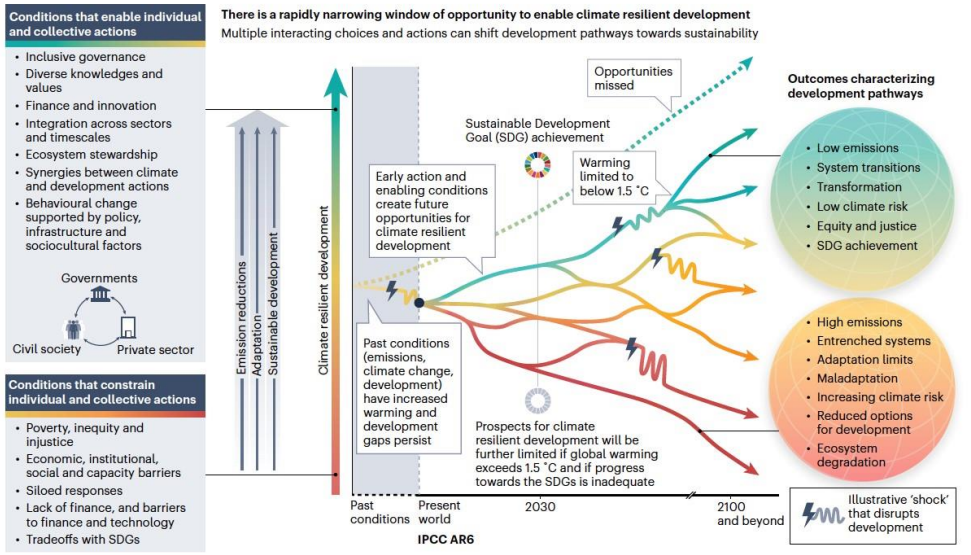
Equitable development pathways and integrative solutions for resilient futures

17. Lisa Schipper from the University of Bonn and Aditi Mukherji from the Consultative Group on International Agricultural Research presented on the synergies and trade-offs between climate action and sustainable development. Mukherji underscored that adaptation interventions offer multiple economic, social, and ecological benefits; however, methodological challenges remain in rigorously linking these actions to measurable reductions in exposure, vulnerability, and hazards as there is limited literature base in this regard. Further, she also indicated that the effectiveness of adaptation interventions in reducing climate risks declines at higher levels of global warming and that there are hard limits to adaptation in response to global warming levels. In highlighting sectoral examples, Mukherji highlighted the water sector, where for instance, adaptation to floods and droughts hazards is most effective up to warming of 1.5 °C and thereafter its effectiveness decreases, and residual climate impacts remain. In agriculture, heat and drought-tolerant seed varieties will not work effectively with increased warming, as experienced by communities in India. Adaptation options which offer mitigation co-benefits were also recognized, and more research and investments is required to ascertain and increase their cost-effectiveness, particularly in land, water, and food systems.

18. Citing examples from the IPBES nexus report and the land use and energy sectors, Shipper reiterated that near-term adaptation and mitigation actions have more synergies than trade-offs with sustainable development. While many climate resilient development pathways exist, she also indicated that these are sensitive to decisions made with a risk of moving towards low climate resilient development. For instance, poor decisions could lock-in communities into low-resilience trajectories, and that their impacts could continue for longer as presented in figure 5. To enable climate resilient development, Schipper highlighted enabling conditions such as inclusive knowledge, diverse knowledges and values, finance and innovation, behavioural change and effective policies and addressing structural barriers related to poverty, inequality and injustice. She cautioned that the window of opportunity to

enable climate resilient development is rapidly narrowing and the choice in development contexts is key.

Figure 5
The enablers, constraints, projections and outcomes of climate resilient development pathways



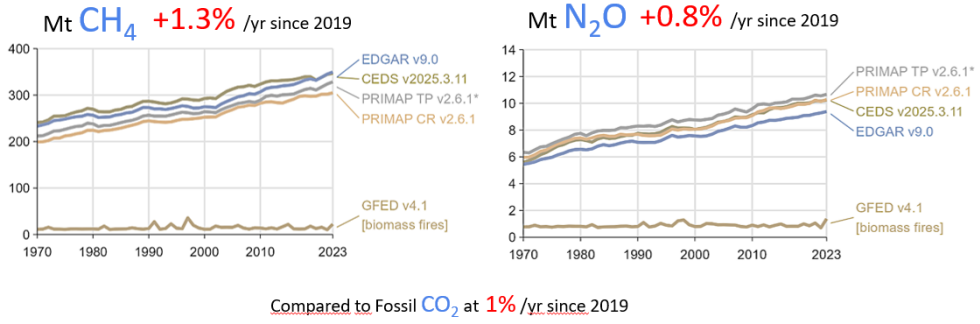
Source: Slide 7 of the presentation by Prof Lisa Schipper and Dr Aditi Mukherji at the RD 17. Available at https://unfccc.int/documents/647808.

Update on non-CO_2 emissions

19. Pep Canadell from the GCP and William Lamb from PIK presented on non-CO_2 GHG emissions and their budgets, with a focus on CH_4 and N_2O, which together account for 22 per cent of anthropogenic GHG emissions. While emitted in smaller quantities than CO_2, CH_4 has contributed up to 0.5 °C of recent warming and is primarily driven by agriculture and waste from manure and landfills. Further, emissions from livestock are comparable to fossil fuel-related CO_2 emissions. Canadell highlighted the importance of understanding both anthropogenic and natural sources and sinks of CH_4 and N_2O, which collectively determine the concentration in the atmosphere and radiative forcing of CH_4. He elaborated that natural systems altered by pollution, warming, and precipitation changes affect natural CO_2 sources and sinks and overall atmospheric concentration. Regarding N_2O, fertilizer and manure are the significant sources, including quantities that make their way to freshwater and coastal zones, which emit N_2O.

20. Overall, emissions of anthropogenic CH_4 and N_2O continue to rise globally, following a linear trend, with CH_4 increasing at 1.3 per cent annually and N_2O at 0.8 per cent since 2019, which is similar to the growth rate of fossil fuel CO_2 as shown in Figure 6. Canadell also illustrated regional reductions of these emissions. For instance, while Annex I countries have seen some emission reductions in N_2O from the agriculture and industrial sectors, and CO_2 fossil emissions from the coal industry, emissions from CH_4 and industrial gases (fluorinated-gases) continue to grow in the past 10 years. Further, the current global CH_4 emissions and projections are not consistent with the Paris Agreement related pathways, which require much lower emissions, a reduction of a third of the emissions. Canadell also presented on the observed changes in the annual growth rates of emissions with varying causes for each year, for instance, from the response of the natural systems to warming, variable climate and pollution. He further illustrated the changes in the natural system, due to its increased sensitivity, and caused by anthropogenic contributions such as wetland emissions and patterns during the Coronavirus disease 2019 which affected sink capacities.

Figure 6
Growth of global anthropogenic methane and nitrous oxide emissions and N_2O emissions



Forster, P. M. *et al.* Indicators of Global Climate Change 2024: annual update of key indicators of the state of the climate system and human influence. *Earth System Science Data Discussions* **2025**, 1–72 (2025).

Source: Slide 5 of the presentation by Dr Pep Canadell and Dr William Lamb at the RD 17. Available at https://unfccc.int/documents/647811.

B. Breakout sessions

1. Latest science in understanding climate change and related impacts

21. The session was co-facilitated by Ladislaus Chang'a and Frank McGovern. Harry Zekollari, from Vrije Universiteit Brussel, presented on glacier mass and associated losses based on modelling of the world glaciers and from the study under GlacierMIP3. Notwithstanding the significant regional disparities in projected glacier loss due to global warming, Earth system modelling indicates that 40 per cent of global glacier mass will be lost at the current warming of 1.2 °C, even without further warming. Further, every degree of warming contributes to glacier mass loss, where every 10th of a degree results in 2 per cent additional global glacier loss. In demonstrating the regional variations in glacier mass loss, Zekollari indicated that European Alps could lose over 50 per cent of their glacier mass while Arctic Canada South could lose over 85 per cent regardless of emissions scenarios. Further, regions have varying sensitivity to temperature, where for instance, the glaciers in High-Mountain Asia lose 3–3.5 per cent of their mass per 10th of a degree of warming, compared to the global average of 2 per cent. By limiting warming to 1.5 °C, Zekollari demonstrated that glacier preservation could double, as reflected in figure 7 below for the various regions, and that losses increase steeply beyond 2 °C warming, with larger losses projected at 2.7 °C and beyond.

Figure 7
Sea ice extent under different temperature projections in the Asian region

Region	Temperature causing 50% loss	% Remaining at 3°C	% Remaining at 2°C	% Remaining at 1.5°C
Tropics (Central Andes, E. Africa, Indonesia)	1.6°C	10%	30%	55%
Caucuses	1.6°C	20%	40%	55%
Alaska	1.7°C	30%	40%	60%
Central Asia	1.9°C	20%	45%	65%
Southern Andes & Patagonia	2.0°C	30%	50%	55%
Western Himalaya, Karakorum & Hindu Kush	2.2°C	30%	60%	85%

*Numbers are in comparison to 2020 levels

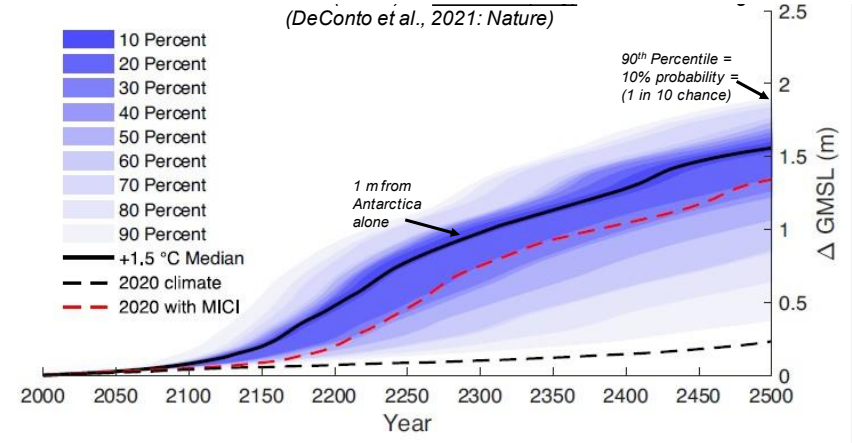
GlacierMIP3 (Zekollari, Schuster et al., 2025, *Science*)

Source: Slide 9 of the presentation by Prof Harry Zekollari at the RD 17. Available at https://unfccc.int/documents/648371.

22. Chris Stokes from Durham University examined the accelerating contribution of melting ice sheets to sea-level rise, based on the publication, "warming of +1.5 °C is too high for polar ice sheets".[8] According to the paper, land ice melt has overtaken ocean thermal expansion as the dominant driver of sea-level rise, and that the contribution from Greenland and Antarctica ice sheets is more than that from mountain glaciers. Under the current warming of 1.2 °C, sea-level rise is accelerating, and it could, according to modelling, go up to 6.5mm per year by 2050 and 1cm per year by end of the century. Henceforth, sea-level rise of one metre of per century will render adaptation difficult to attain.

23. Since the 1990s, combined ice sheet mass loss has quadrupled, losing around 370 billion tons of ice annually and adding about 25 mm to global mean sea-level, and the contribution is accelerating for the Greenland ice sheet. Further, paleoclimate records also indicate that similar or lower CO_2 concentrations in the past led to sea levels of between 2-20 meters higher, suggesting that current warming could trigger comparable responses, and that these changes are already happening quickly. Stokes stressed that while 1.5 °C remains a critical threshold and is essential, it will not slow sea-level rise as shown in figure 8, and limiting long-term temperature to 1.0 °C or lower, may effectively slow sea-level rise from ice sheets to manageable levels of approximately 10 mm per year. Further, other studies demonstrate that the current warming of +1.2 °C is adequate to trigger collapse of the Greenland and West Antarctic ice sheets.

Figure 8
Global mean sea-level rise projections for the Antarctica at 1.5 warming



Source: Slide 5 of the presentation by Prof Chris Stokes at the seventeenth research dialogue. Available at https://unfccc.int/documents/647880.

24. Shraddha Gupta from Ludwig-Maximilians-Universität München presented on means for scaling-up CDR effectively with insights from the EU horizon ResCUE project[9], particularly based on Earth system modelling, interdisciplinary assessments and global tracking. The various CDR approaches on land and ocean where explained and Shraddha highlighted the variations in their levels of readiness, sequestration potential, durability, mechanisms and impacts; and the study focussed on modelling of afforestation/reforestation, BECCS, ocean alkalinity enhancement and DACCS.

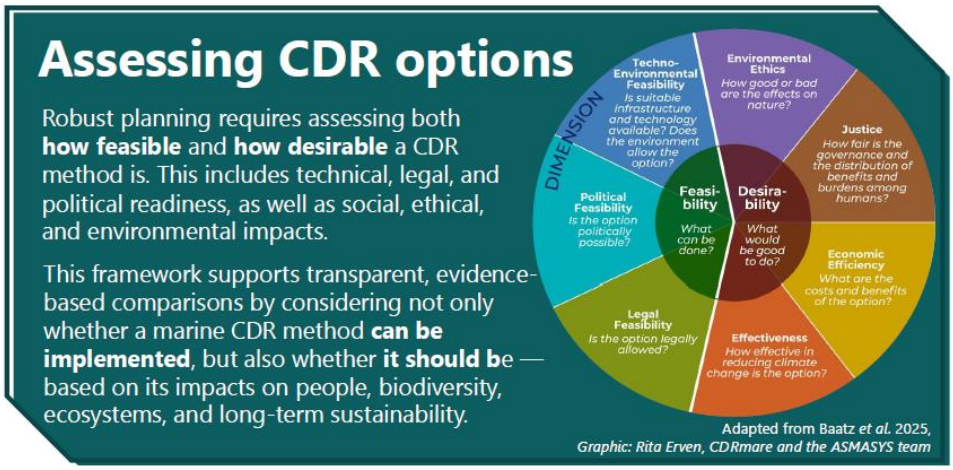
25. She highlighted that all 1.5 °C warming scenarios require deep near-term emission cuts as well as CDR for offsetting residual emissions, especially in hard-to-abate sectors, and achieving net-negative emissions. The current deployment of CDR, at approximately 2.2 $GtCO_2$/year, is far below the required levels. Specifically, an additional 1-3 $GtCO_2$/year removal is required by 2030 and 2–7 $GtCO_2$/year by 2050, compared to 2020 levels, and the most ambitious national CDR proposals are at the lower end of this range. Further, according to the research presented, most current CDR comes from conventional methods such as afforestation and reforestation, while novel methods such as BECCS, biochar, and DACCS

[8] See https://www.nature.com/articles/s43247-025-02299-w.
[9] See https://rescue-climate.eu/.

represent less than 0.1 per cent of the total CDR deployed. Largest afforestation/reforestation-based CDR are in Europe and east-Asia, with substantial contribution from tropical regions.

26. Following modelling under CDRTerra, simulations show that ambitious afforestation/reforestation, pledges of 35 million hectares by 2100, if deployed early and persistently, can mitigate temperature overshoot by lowering global peak temperatures, reduce end-of-century warming by 0.2 °C, and shorten overshoot by 13 years. In comparing the approaches, CDR potential for afforestation/reforestation was greater for short to medium term targets and that BECCS, particularly bioenergy plantations, offered long-term benefits in most regions. When combined, land and ocean-based CDR methods show nearly additive effects linearly, and there is no compromise of individual approaches, therefore emphasizing the significance of a diversified CDR strategy. Gupta highlighted the role and importance of adopting holistic frameworks when deploying CDR, beyond technical modelling, to distinguish and understand readiness, feasibility, desirability, economic viability, environmental integrity and socio and ethical impacts using frameworks such as the CDRmare framework[10] to guide dialogue and action as reflected in figure 9 below.

Figure 9
The CDRmare framework for assessing CDR options



Source: Poster presentation by Shradda Gupta at the RD 17. Available at https://unfccc.int/documents/647886.

27. Renzo Taddei from Sao Paolo University presented on integrating Indigenous knowledge into climate change research, particularly adaptation-related research. He highlighted the recognition and progress made by the IPCC in regard to Indigenous knowledge for the AR7 and the challenges in advancing this. Currently, common elements of Indigenous knowledge related to Earth system science are on environmental change indicators and biodiversity conservation, as observed by Indigenous Peoples as well as adaptive strategies undertaken by them. As a result, common gaps when considering the research relates to geographic and thematic disparities, fragmented data, demographic variables such as gender, age group and religious affiliation, and variations in the scale of the research. For instance, Indigenous knowledge and strategies in the Africa region have a focus on Indigenous agricultural practices, Arctic Indigenous groups have more knowledge on ice ecosystem; sea-level rise and flooding in Bangladesh and Philippines or water management in the Sahel. The unique interaction of Indigenous communities with climates and ecosystems, which is richly documented, is not fully recognized and utilized in climate and ecological sciences, a gap noted by IPCC and IPBES as well. Social organization and cultural elements of such communities are important, particularly when climate action requires system-societal-transformations

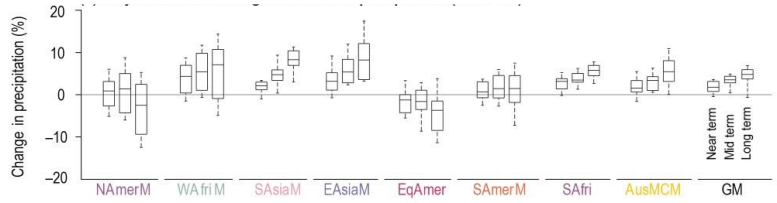
28. Taddei also highlighted methodological practices and gaps in efforts aimed at integrating Indigenous knowledge with mainstream (also referred to as western) research systems. For instance, the process of translating Indigenous knowledge into mainstream

[10] See https://cdrmare.de/en/.

scientific process is also viewed as "validation of Indigenous knowledge" in which views that do not subscribe to western ways are often discarded. Some Indigenous authors therefore have supported presenting different forms of knowledge side by side and discourage the fusion of the knowledge. He therefore indicated the need for further research on the procedural strategies in synthesizing such knowledge, and the need for greater collaboration between Indigenous and non-Indigenous scholars and wider stakeholders, including for public policy. Particularly, new procedures for research could be co-produced with Indigenous scholars, using methodologies that they consider as legitimate, guaranteeing their sovereignty over the research data and outcomes. Taddei highlighted the CARE protocol which is advancing this approach, the Local Communities and Indigenous Peoples Platform as a platform for dialogue on the topic, and that fundamental transformations supported by adequate funding are still required across research practices.

29. Annalisa Cherchi from the National Research Council of Italy presented a global perspective related to the future of monsoons in a changing climate based on the World Climate Research Programme's monsoon panel and GPEX lighthouse activity[11], which focuses on improving precipitation predictions globally. She elaborated on the variations between global and regional monsoons, as reflected in IPCC assessments, and attribution of monsoon precipitation changes including impacts from aerosols and GHGs. She highlighted that monsoons are an important and main source of precipitation for many regions, including in the Asian region, where considerable information and understanding is present. While past changes in monsoon precipitation were influenced by aerosols, tending to suppress rainfall, future scenarios show an increase in monsoon precipitation, driven by the increase of anthropogenic influence-GHGs as demonstrated in figure 10. Increasing and changing precipitation in the long-term is particularly projected for the Asia region, in comparison with present day. Using CMIP6 simulations, the research demonstrates an extension of monsoon season, with delayed retreat, as well as a clear link between increasing mean precipitation and extreme rainfall. She reiterated the significance of enhancing observations to improve modelling of precipitation including its respective drivers and referenced the work of the GPEX in this regard.

Figure 10
The projected future change in monsoon precipitation



Box TS.13, Fig. 1(a,c)

Percentage change in projected seasonal mean precipitation over global and regional monsoons domain in the near term (2021–2040), mid-term (2041–2060), and long term (2081–2100) under SSP2-4.5 based on 24 CMIP6 models

Source: Slide 4 of the presentation by Prof Annalisa Cherchi at the RD 17. Available at https://unfccc.int/documents/647883.

Discussions

30. During the question-and-answer session, participants discussed the need for effective messaging of scientific research outcomes with the view of better informing policies, such as on the urgency of sea-level rise projections and tipping points of ice sheets. Participants also discussed the internal variabilities of sea-ice extent, the implications of temporarily overshooting 1.5 °C and of the tipping points of oceans, particularly for small island developing States, as well as related research needs and gaps. Further, ways of integrating information and knowledge of tipping points in adaptation planning, particularly in least developed countries was discussed. Participants also supported and highlighted the need to integrate high resolution regional models to fill gaps in, and compliment global models with the view of fully understanding feedbacks, such as in sea-level rise. Opportunities, barriers, and knowledge gaps related to the deployment of CDR at large-scale, and particularly for

[11] See https://www.wcrp-climate.org/gpex-overview.

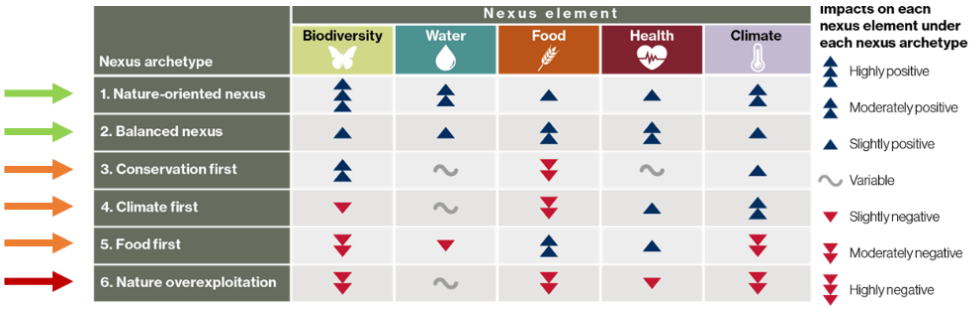
marine-based CDR and role of IPCC in this were discussed, noting the current low levels in adoption. In regards Indigenous knowledge, participants also discussed how IKS can contribute to information of extreme events such as mobility related to heat stress. They also discussed the research needs to enable adequate and downscaled climate data to support effective adaptation, particularly in vulnerable countries.

2. Climate action and sustainable development nexus

31. The session was co-facilitated by Patricia Nying'uro and Pam Pearson. Co-Chairs of the IPBES Nexus Assessment Paula Harrison and Pamela McElwee presented key findings from the assessment which focuses on the interlinkages among biodiversity, water, food, health, and climate change, also referred to as the five nexus elements. The IPBES assessment was based on over 6,500 sources, including Indigenous knowledge literature, and produced by over 165 experts and supported by over 70 contributing authors. The assessment indicates that while global crises associated with the nexus elements are deeply interconnected, policy responses remain largely siloed, which can result in efforts being ineffective and counterproductive or even lead to compounding negative effects on the elements. The assessment therefore demonstrates how nexus approaches are important to tackle global crises and avoid unintended consequences as well as unplanned trade-offs and leading to sustainable futures.

32. The assessment analyzed 186 future scenarios, identifying that only those grounded in integrated, sustainable development pathways yielded positive outcomes across all five domains, as seen in figure 11. For instance, siloed strategies (*orange arrows in figure 11*), such as focusing solely on climate mitigation, often generates trade-offs with negative effects on biodiversity, food, and water systems, while well-coordinated, integrated and timely responses (*green arrows in figure 11*) can deliver synergistic benefits across all nexus elements.

Figure 11
Interactions of sustainable development actions and nexus elements



Source: Slide 4 of the presentation by Prof Paula Harrison at the RD 17. Available at https://unfccc.int/documents/648317.

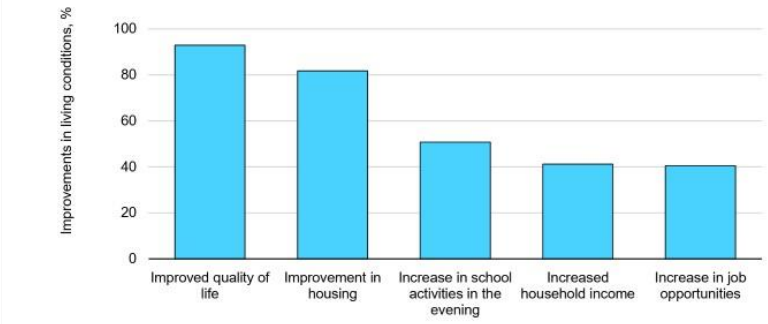
33. More than 70 response options were identified and placed into 10 categories including restoration ecosystems, sustainable consumption, integrated planning and risk management, to demonstrate their levels of impact. Most of the options provided large benefits across the five nexus elements, such as coastal ecosystem restoration which has multiple co-benefits for biodiversity, climate resilience, health, food security, and water quality. The assessment also considered equity, cost, technical feasibility and social acceptability and acknowledges that while trade-offs exist, their management is essential. Prominently, these options also align with and advance the goals of other global policy frameworks, such as the SDGs, the Global Biodiversity Framework targets, and the Paris Agreement goals. Harris outlined how the IPBES assessment provides decision-makers with the best-available evidence and tools as well as highlights the role of different actors to collectively tackle the global crises.

34. Juliette Denis-Senez from the International Energy Agency presented an update on the work of the Global Commission on People-Centered Clean Energy Transitions,[12] specifically the blueprint for action on just and inclusive energy transitions. The

[12] See https://www.iea.org/programmes/designing-for-fairness.

Commission's blueprint is structured around 10 voluntary principles for just and inclusive energy transitions which were endorsed by the G20 leaders. It aims to serve as a guidebook for countries in implementing policies in their domestic setting and acknowledges that many countries' policies are already aligned with the principles. The blueprint highlights key aspects of focus for each principle and includes over 60 case studies, representing different geographical and local contexts, demonstrating that inclusive energy policies also lead to economic and wider societal benefits. For example, Brazil's Light for All program, improved both rural energy access and other socio-economic benefits as shown in figure 12. In Dublin, a targeted scheme for residents with chronic illnesses offered home retrofits that reduced energy poverty and improved well-being. The Commission underscores the need for context-specific policy design and implementation, showcasing successful approaches such as Spain's just transition strategy since 2019 where regional socioeconomic assessments where conducted to support energy transition and diversification strategies. Further, Denis-Senez highlighted the importance of identifying needs of stakeholders, as done by South Africa's Presidential Climate Commission that brings together stakeholders in labour, civil society and industry to coordinate transition to clean energy.

Figure 12
Socio-economic benefits of energy policies as reflected by the Brazil Light for All program



In Brazil, a long-term programme aiming to improve energy access has also delivered significant social and economic benefits for participants.

Source: Slide of the presentation by Juliette Denis-Senez at the RD 17. Available at https://unfccc.int/sites/default/files/resource/2.%20Energy_Transition_IEA.pdf.

35. Denis-Senez also highlighted the need to continuously monitor the effectiveness of the policies. Accordingly, the Commission plans to publish an Indicators Handbook, which is a non-prescriptive resource for governments and stakeholders to support tracking progress against the 10 principles, offering a menu of indicators, which are context specific, and informed by regional workshops. The blueprint and the upcoming indicators handbook will contribute to the G20 action agenda, to inform discussions of the G20 Ministerial meeting and Energy Transition Working Group, and COP-related processes.

36. Jessica Strefler from PIK presented on how sustainable development and climate protection go hand in hand. She highlighted that damages from climate change resulting from current policies lead to economic losses and threatens sustainable development, and especially for lower-income countries who are projected to have significantly reduced income of up to 30 per cent. Further, repeated natural disasters threaten to reverse development gains and overburden the national capacities of these countries. Accordingly, efforts towards SDGs require holistic pathways as well as ambitious and integrated strategies that include strong climate protection. Therefore, mitigation pathways that are identified through targeted policies, should consider broader the sustainability context with the view to enhance synergies and mitigate trade-offs.

37. Research demonstrating multiple mitigation pathways and their impacts on SDGs was presented, such as in food and land systems; where high food and feed demands has implications on forestry restoration, biodiversity conservation and ecosystem services, hence requiring holistic approaches. Additional studies also exist on the benefits of dietary shifts towards achieving 1.5 °C, as well as studies that discuss international and intergenerational equity and impacts of climate change on economic inequality. Strefler illustrated three socio-

development narratives related to economy-driven innovation, resilient communities and managing the global commons, and how they can significantly enhance SDGs outcomes and promote economic gains within and across countries. She confirmed that current development trends are off-track towards meeting SDGs and that a whole-of-systems transformation approach is needed to reduce inequality and fulfil both SDGs and the Paris Agreement goals.

38. Nobuhito Mori from the Disaster Prevention Research Institute of Kyoto and Yokohama National University presented Japan's approach to DRR and infrastructure development through the integration of climate change projections into planning and policy. He elaborated on how the country facilitates collaboration between research and implementation to design, plan and implement adaptation strategies and key infrastructure. The Japan climate change report, published every five years, includes national assessment reports, datasets and information from climate projection research, and is aimed at providing information on observed and projected changes. The national report comprises of a summary for policy makers, detailed edition for experts and simplified summaries for citizens. The datasets, such as that of 2022, includes large ensemble datasheets, model simulations of up to 5km regional resolution, and projections at various warming levels which also includes extremes.

39. In reflecting how Japan applies these projections to support resilient infrastructure development, Mori cited the updated river flood control plans, which incorporates projections showing increased rainfall and flood risk; coastal protection plans which account for sea-level rise and typhoon-induced storm surges, and ocean waves; and port plans that consider sea-level rise as well as involving both public and private sectors. Additionally, he outlined the ongoing upgrade of storm surge barrier gates, such as in Osaka, which consider future emissions and warming scenarios. Mori elaborated that Japan is upgrading adaptation-related infrastructure and applies integrated flood risk management in this regard, which goes beyond seawalls and includes relocation and second line protection.

Discussions

40. Participants discussed how the research and information, such as from the IPBES nexus assessment report can be used to advocate for stronger climate action, particularly in mitigation and the research needs to achieve this. Further, they also reflected on the extent that other SDG-related priorities such as poverty eradication, energy poverty and gender were considered in the IPBES scenarios. In relation to global sustainable development scenarios, participants discussed the application, including related uncertainties, of the studies and the policy options at national and regional levels and across various scenarios of warming, the use of IAMs and drivers of economic redistribution. Participants also highlighted issues related to gaps in means of implementation and support, pre-2020 ambition and differentiation of current ambition, as well as response measures that impact climate action.

C. Summary of poster session

41. The research dialogue featured 16 scientific posters on multidisciplinary research and latest scientific information related to the themes of the dialogue and are summarized in this section. Participants to the dialogue were invited to engage with the poster authors and contributors. Posters were available for a period of one week during the conference, and digital posters are available on the event webpage as reflected below:

(a) Akihiko Ito (Models for evaluating GHG budgets and short-lived climate forcers) presented tools for evaluating and monitoring emissions for climate policy and multi-scale climate planning.

(b) Harry Zekollari et al. (Glacier preservation doubled by limiting warming to 1.5°C versus 2.7°C) demonstrated current trends in glacier mass and how glacier loss could be significantly reduced under low-emission scenarios.

(c) Chris Stokes et al. (Returning closer to 1°C or below is essential for polar ice sheets) presented on the status of tipping points in the cryosphere and flagged potential impacts from projected warming scenarios.

(d) Shraddha Gupta et al. (Scaling up CDR Effectively) explored modelling tools and interdisciplinary insights for advancing and upscaling CDR approaches.

(e) Setu Pelz and Elina Brutschin (JustMIP: Advancing Justice Considerations in IAM Scenarios) illustrated means for integrating equity into IAMs for global climate policy.

(f) Joannes Maasakkers et al. (Observation-based opportunities to achieve vital methane emission reductions) provided observational tools for targeted tracking and action for methane emissions reduction.

(g) Susana Hancock (Global Carbon Budgets) highlighted trends and implications of emissions from permafrost.

(h) Matti Goldberg (Understanding warming-driven emissions from ecosystems) examined how indirect ecosystem feedbacks could affect climate action efforts.

(i) Amir Delju (State of the Global Climate 2024) provided an overview and update on the global climate indicators, including climatic extremes.

(j) Tejal Kanitkar and Thiagarajan Jayaraman (Low emissions and climate-resilient development pathways) outlined gaps in the consideration of equity in current emissions pathways and corresponding implications for attaining sustainable development.

(k) Greta Dekker, Edward Sparkes, and Saskia Werners (Mapping synergies and trade-offs between adaptation, mitigation and development) presented projects from Germany and Kenya that demonstrate tools to advance synergies and minimize trade-offs between climate action and sustainable development.

(l) Saki Ohkubo Miyagi et al. (Climate Change in Japan 2025 report) presented the latest climate change report which reflects observed and projected changes, as well as informing policies.

(m) Valentina Nyame and Lisa Schipper (The Uneven Burden: How Climate Adaptation Affects Men and Women in West Africa's Coastal Areas) explored disproportionate impacts of climate change and how closing the gender gap addresses structural inequalities in Ghana and Benin.

(n) Cheryl Jeffers (1.5°C-aligned resilient development for small island developing states) illustrated the climate-related vulnerabilities of SIDS and highlighted current efforts and enablers for climate action in the region.

(o) Maria Walawender (Climate change and human health) examined the impacts of climate change on human health and outlined pathways and opportunities for action.

(p) James Kirkham (Forest and Ice Tipping Points in the Earth System) shared critical Earth system thresholds, including of the Amazon Forest, Antarctic and Greenland ice sheets.